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Arshan palaeoseismic feature of the Tunka fault (Baikal rift zone, Russia)

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ABSTRACT

The traditional concept of the rift development of flank depressions in the Baikal rift zone is now doubted in view of some indicators for compression deformations identified by the seismogeological and geodetic methods. Besides, the paleoseismological investigations revealed seismogenic strike-slips and reverse faults in the Tunka fault zone that is a major structure-controlling element of the Tunka rift depression. However, a detailed study of the upslope-facing scarp in the Arshan paleoseismogenic structure zone has shown that its formation might be due to rift mechanism of basin formation. Age estimation has been made for the previously unknown pre-historic earthquake whose epicentral area coincides with the western flank of the Arshan paleoseismogenic structure. Judging from previously determined ages of paleoearthquakes, the mean recurrence period for faulting events on the central Tunka fault is 2780–3440 years.

1. Introduction

The Tunka depression consists of six different-sized basins separated by basement uplifts on the southwestern flank of the Baikal rift zone (Fig 1). Early geological investigations (Florensov, 1960, 1969; Zorin, 1972; Solonenko, 1975) showed that the Tunka depression is similar in geological-tectonic structure and developmental history to the inland basins of the central and northeastern branches of the Baikal rift. Abundant evidence obtained from a decade-long, comprehensive study of rift basins and basin-bordering mountains, indicates a complicated mechanism of interaction between rifting and formation of domal horst structures covering an area considerably larger than the Tunka rift. The development of rift basins occurs in the context of a general uplift of the area south of the Siberian platform, including the mountains bordering it on the south (Sharyzhalgai ridge, Baikal dome and others), with an absolute subsidence related only to the proper Tunka basin. Another five satellite basins have undergone only relative subsidence, i.e. the basin bottoms, when uplifting, do not keep pace with the basin-bordering hilltop and base surfaces in growth. The marginal flank basins – Mondy and Bystrinsky (13 and 14 in Fig. 2) – have already ceased to be areas of sedimentation and become the elements of inner structure of inversion blocks of inter-rift mountain ridges. The bottoms of these basins are tectonically deformed. The previously existing sedimentation surfaces are distorted, broken into steps, and intensively eroded.

The inversion uplifts also involve large areas of major rift basins (Khoitogol, Tunka, Tora) (labels 7, 10, and 12 in Fig. 2). Most of these areas are adjacent to crystalline interbasin uplifts and the bottom part of the intense domal uplift of the Khamar-Daban ridge. At present, about 40% of the Tunka basin area has ceased to be the scene of sedimentation (Shchetnikov, 2009; Shchetnikov et al., 2012).

The northern sides of the Tunka and Tora basins are controlled by the Tunka fault zone, whose eastern flank lies within the Tora basin and Elovsky ridge. Paleoseismic investigations (Chipizubov et al., 2003) have shown seismogenic deformations of the reverse-scarp type that were produced by numerous reverse slips. Seismotectonic deformations that are exactly the opposite of typically rifting deformations, i.e. with near-horizontal compression and extension axis normal to the earth surface, are characteristic of some $M > 4$ earthquake focal mechanisms (Fig. 2). Strike-slip deformations along the Tunka fault are indirectly indicated by fractures in the crystalline basement rocks and sometimes by river bends. Linear NE-trending folds in sedimentary fill of basins (Florensov, 1960) may be also indicative of probable compressions.

The authors of this paper believe that the strike-slip motion on the eastern part of the Tunka fault may be related to the eastward motion of the Tora basin as a structure developing on the Precambrian basement of the Slyudyanka block, and consequently the fault is part of the southwestern (hanging) side of the Main Sayan fault. The eastern segment of the Tunka fault splits the northern margin of the Slyudyanka block forming a buffer zone (the Derbinsky block) for displacement amplitude distribution between two large tectonic elements of the crust – Siberian platform and its southern folded border. Longitudinal extension of the Tunka basin

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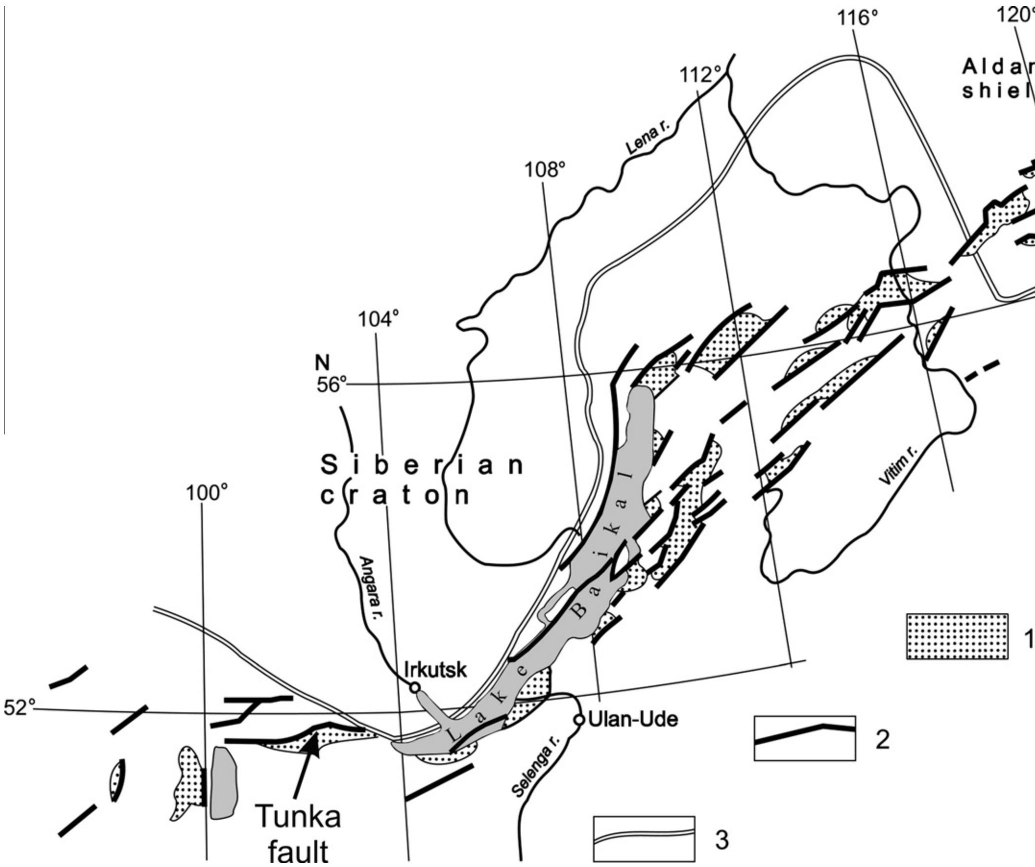

Fig. 1. Structural position and morphology of the Baikal rift system (after Logachev (2003)). 1 – rift basins, 2 – faults of various geometries, 3 – boundary between the Siberian craton and Sayan-Baikal orogenic belt.

predetermined its transverse divisibility to form basement uplifts between some basins, of which the most important is the proper Tunka basin whose northern side has been complicated by dislocations of the Arshan paleoseismogenic structure.

The Arshan structure was first described by seismogeologists from the Institute of the Earth's Crust of Siberian Branch of Russian Academy of Sciences (Solonenko et al., 1971; Solonenko, 1975), with an emphasis on normal-fault scarps and troughs as indications of paleoseismicity. Fault scarps formed by down-dip faulting of the Pleistocene terraces are 5–20 m high. The total height of the scarps is up to 50 m in the watershed areas, and testifies to a general effect of "several certain intensity earthquakes that took place over the last several hundred–first several thousand years". The troughs at the base of the scarp are up to 3–4 m deep and 10–70 m wide. Geomorphological research suggests that genetically the Arshan structure is "a fault with downthrown basin-bounding side, which follows the displacement along the major plane of the Tunka rift fault" (Florensov, 1969). The estimated intensity for the earthquake that produced the Arshan structure is at least equal to 10 points by the MSK-64 scale ($M > 7$).

Dislocations on the Arshan paleoseismogenic structure have a genetic link with near-horizontal extension, as evidenced by grabens at the bottom of fault scarps, cracks, and antithetic faults identified by geophysics. It is in this fault segment to which the Arshan structure is confined, that the gradient of vertical deformation attains its maximum as compared to other segments of the Tunka fault. Near the Arshan structure, there is evidence for the maximum downwarping of the basin basement. In this connection, the central segment of the Tunka fault can hardly be viewed as the site of even local reverse-fault type deformations, of the type that are common east of the basin border. However, within the Arshan structure the authors of this paper have found a 350-m long and ~5-m high reverse scarp whose existence is hard to explain in general geodynamic context of the southwestern Pribaikalye. The authors have attempted to solve this problem by a detailed study of the deformation in relation to the development of the Arshan dislocation as a whole.

2. Palaeoseismic features

Paleoearthquakes on the Arshan structure were first dated in the early 1990s (McCalpin and Khromovskikh, 1995). These results were obtained from C-14 dating of the samples collected in 1991 from buried soils in two quarry trench walls (A-6 – upper quarry exposure, A-7 – lower querry exposure), in a shallow trench near the seismic station (trench A-5 at the base of the normal fault bounding the 3rd terrace), and in a pit on the first terrace (AT-1). Note that trenches were excavated only in the central part of the structure, in the deposits on the alluvial fan terraces aligned parallel to the Kyngarga River (Fig. 3). For the present study we made three new excavations at variable distances west of the Kyngarga River. The revealed deformations in these new excavations provided new and stronger evidence in support of the paleoearthquakes identified by McCalpin and Khromovskikh (1995), and also identified a previously unknown paleoevent confined to the western flank of the Arshan structure.

This paper focuses on the development of Late Quaternary seismotectonic deformation processes on the segments of Tunka fault zone west of the Kyngarga River, which differ in the fault plane